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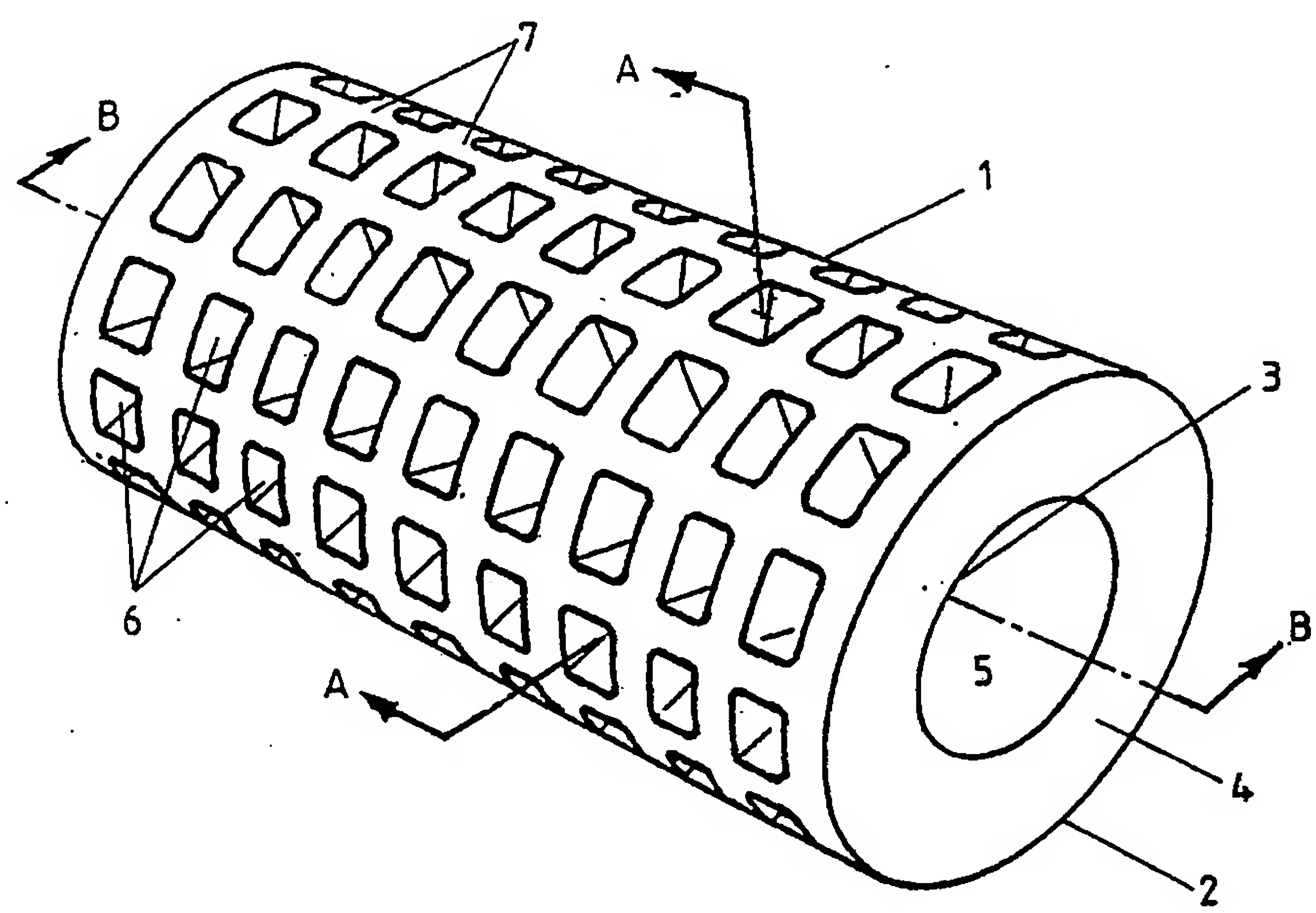

(57) Abstract

A shock absorbing device of substantially polyurethane construction is described in which there are provided a plurality of cavities in the outer surface of the device. The characteristics of the polyurethane material varies in layers between the outer surface and the inner surface of the device being hardest at the outer and inner surfaces and less hard between the surfaces. The device finds applications as a marine fender.

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SHOCK ABSORBING DEVICE

This invention relates to a shock absorbing device formed of polyurethane material and, a method and apparatus used to manufacture such a polyurethane shock absorbing device. In particular it relates to a shock absorbing device of substantially cylindrical or tubular construction.

Shock absorbing devices of cylindrical construction which are used for protection, find applications in a wide variety of situations. At one extreme of size are marine fenders which are employed to minimize the possibility of damage to wharves and ships during docking procedures, or in heavy seas. At the other extreme of size are shock absorbing components utilised in machines and instrumentation. Whatever the application the aim is to produce a device having stable operative characteristics and large energy absorbing ability, relative to its mass and size, coupled with a maximum reaction force when compressed over its designed deflection characteristics which do not exceed the strength of the surfaces or members being protected.

The use of marine fenders to protect ships, wharves, drilling rigs and similar marine structures is well known. Typically these are of substantially cylindrical or tubular construction and may be of circular, D, trapezoid or rectangular cross-section. Various other designs have been employed including inflatable fenders and floating fenders.

Typically these tubular fenders are comprised of rubber material or in particular styrene butadiene rubber (SBR). In addition some fenders are formed with metal or hard plastic sections or inserts to provide additional durability, toughness and means of mounting.

These tubular fenders are usually designed to absorb energy by axial or radial elastic compression. The majority of fenders loaded axially are contained within or attached to complex rigid structures or have sophisticated mounting requirements and shapes to handle large deflections which are desirable to minimise the reaction force, which becomes critical when cushioning larger vessels especially those above 150,000 tons, as their steel plate thickness does not increase in direct proportion to their mass. Thus their cost

effectiveness becomes less with increasing size. In addition any of these mounting structures which have a considerable inertial mass which is added to the inertial mass of the rubber fender further increases the reactant force to a degree where the vessel's hull is damaged especially where the closing velocity is high.

Similarly tubular fenders which are compressed radially and having other than a substantially circular cross section also contain complexities which reduce their cost effectiveness. Furthermore as these more complex shapes need to be molded as monolithic rubber members for maximum effectiveness and durability there is a practical limitation to their unit size and mass dictated by technological and tooling cost considerations.

Conversely currently used rubber tubular fenders which are compressed radially and having substantially circular cross sections may be manufactured by a process whereby a strip of uncured rubber is wound around a mandrel until the desired diameter is reached. This monolithic lamination is then contained, and cured with heat and pressure. This allows for the manufacture of very large fenders weighing up to 15 tons and costing tens of thousands of dollars. And although their energy absorption per unit mass may not be as efficient as smaller more complex shapes their relatively lower manufacturing maintenance and mounting costs sees their increasing use, even in smaller sizes, typically of 0.4 m O.D. and 0.2 m I.D. where they are installed in lengths secured to docksides or vessels by wires or chains threaded through their bores. Even so it will be appreciated that the larger items are expensive and both labour and material intensive to produce and difficult to handle.

In addition the above fenders commonly of substantially cylindrical construction with a hollow core may be supported by a member or members passed through the hollow core and each end is attached to the marine structure. The fender is thus slung against the side of the structure. A common support member is a semi-elliptical metal rod supported by chains.

These fenders have different operative characteristics depending on the degree of compressive load to which they are subjected. For low loads, the amount of energy absorbed is essentially a linear function of the radial

deflection of the fender surface and the Shear Modulus G of the rubber which is dependant on the IRHD of the rubber. For thin sections the load-deformation behaviour has been derived by considering the bending moment that exists at any cross-section. For thick sections the shearing forces and normal forces must be considered. In this regime the hollow core of the fender is flattened. At the point where the hollow core has been totally compressed the energy absorbing characteristics change to those of a solid pad under compression and the IRHD of the bulk material determines the reactant force. Thus for this type of fender the best performance is achieved where the designed fenders absorb the energy of impact before reaching the regime in which the characteristics are those of the bulk material.

The publication titled "Theory and Practice of Engineering with Rubber" which has a Library Congress catalogue card number 78-325872 gives a comprehensive outline of rubber design and calculation principles and specifically pages 146 to 165.

With respect to the radial compression of long hollow substantially circular cylinders where the ratio of the external diameter divided by the internal diameter is generally less than 2.5 and referring to the above publication page 148 onwards and applying general engineering principles with respect to bending stresses in curved beams it can be appreciated that the maximum fiber stress due to bending moments occurring at the diametric plane normal to the applied force. And provided that the cross section is regular, and the shear modulus is essentially constant over the curved section then the fiber stress varies from a maximum compressive stress at the internal surface to zero at the neutral axis to a maximum tensile stress at the external surface. For this situation the stress distribution is of a hyperbolic nature and the neutral axis is located at a radius other than the radius of the centroid axis and also that in this situation the neutral axis is located between the centroid axis and the center of curvature; this always occurs in regular sectioned beams of constant material strength. Of course this may not be the case if the sectional area or material strength varies in a radial direction.

Furthermore it can be shown by calculation that for a symmetrical section the maximum bending stress will always occur at the inside fiber surface of the

fender. Calculations show that for a fender of O.D. divided by I.D. = 2 this bending stress at the inner surface is approximately 25% higher than that at the outer surface.

Naturally it is also evident that for a constant reacting force supplied by a fender the discussed bending stresses applied to the fender fibers increase as the ratio of the O.D. divided by the I.D. decreases. For example decreasing the ratio from 2 to 1.5 doubles the bending stresses.

It is an object of this invention to provide a shock absorbing device which provides protection against damage due to impact which is simpler to produce and easier to handle than existing devices. Furthermore the shock absorbing devices of this invention have higher load bearing capacity per unit weight (and compared to existing products) resistance to tear and cut propagation than existing products.

A basis of this invention is that a suitable shock absorbing device can be produced from polyurethane elastomer material. Such fenders perform at least as well as rubber or SBR equivalents and in many aspects are far superior.

Previously the use of polyurethane in large shock absorbing devices has been limited due to the higher density of solid, high performance polyurethane materials. This increase in the mass coupled with the higher cost of the raw material makes it uneconomical to produce shock absorbing devises of identical design to current rubber devices. It is a discovery of this invention that by introducing cavities into the outer surface of the shock absorbing device, the total amount of polyurethane material can be reduced without seriously affecting the shock absorbing properties of the device. There is a further discovery of this invention that the hardness of polyurethane may be varied between the outer surface and the inner surface in such a way that the shock absorbing properties of the device are not degraded, but the total amount of polyurethane material used is reduced. The net affect is a polyurethane shock absorbing device which has a number of advantages over rubber equivalents.

Therefore according to one form of this invention although this need not be the only or indeed the broadest form there is provided a shock absorbing device

comprising polyurethane material, said shock absorbing device being of a substantially cylindrical construction and having an outer surface, an inner surface, and two end surfaces said inner surface defining a void through which a supporting member may pass.

In preference the shock absorbing device is of circular, polygonal or D cross-section.

Polyurethane has a number of advantages for use in shock absorbing devices. Some of these are that the devices can be moulded from liquid feedstock which gives considerably more control than existing hot moulding techniques employed with current rubber devices. The durometer hardness and toughness of the polyurethane can be readily varied during manufacture by varying the composition and proportion of the precursor materials. It can be cast to be completely free of voids, defects and delaminations or alternatively it can be cast as lower density microcellular foam. Furthermore the cure is complete and even.

Properly formulated polyurethane materials are not susceptible to surface stress cracking or flex-fatigue in the way that other currently used rubbers are when attacked by oxygen and ozone. The materials are therefore more resistant to the effects weathering, than are currently used rubbers and can be expected to have a longer life in most applications.

In preference there are provided a plurality of cavities formed in the outer surface and extending towards the inner surface.

In preference the cavities are formed by a web of walls which are generally of similar cross-sectional width and the depth of which is a substantial proportion of the total thickness of the cylindrical wall.

By forming a plurality of cavities in the outer surface the total volume of polyurethane in a shock absorbing device is reduced. This both reduces the total weight of the device and reduces the cost of its production.

If all other things remained unchanged, the introduction of cavities to a shock absorbing device would reduce its load bearing capacity. More specifically the

ability of the device to absorb and dissipate the kinetic energy of an impact is reduced. The benefit of the polyurethane materials is that this loss of load bearing capacity can be compensated for by varying the formulation hardness without a major deterioration of other properties. An added benefit is that by increasing the hardness the abrasion and cut resistance of the surface of the device is improved and its coefficient of friction is reduced. By referring to the hardness it is meant the Shore A hardness as measured by the indentation test.

By increasing the hardness of the material the shear modulus is increased and the energy absorbing properties of the device, under conditions of compression when the central void has collapsed, are degraded and the reacting force rises abruptly.

This problem is overcome by varying the hardness of the bulk material in layers between the inner and outer surfaces. Such variation of hardness is not as readily achievable in the manufacture of current rubber devices. The polyurethane is formulated to provide the highest hardness in layers forming the inner and outer surfaces where the highest fibre stresses are and where the most arduous conditions exist. The lowest hardness is in a layer formed at the neutral axis of the device. The neutral axis is that radial distance from the center of curvature within the curved rubber section undergoing stress whereby the tensile and compressive fibre stresses approach zero.

Accordingly, in a further feature of this invention there is provided a shock absorbing device in which the polyurethane material is of a different characteristic at a first radial distance from the inner surface as compared to another radial distance from the inner surface.

In preference there can be provided a skin effect so that an external surface is made and formed from a polyurethane material which has substantial resistance or is in effect a harder material while the material other than the outer skin is of a softer type providing therefore more potential for energy absorption, especially when the central bore is closed. Furthermore it is an advantage of the method of production of a shock absorbing device of this type that fibres can be introduced into layers during moulding. Therefore, the outermost layer can be of fibre reinforced polyurethane material which has considerable advantages in resisting

weathering. A protective coating of polyurethane may also be provided to further enhance weatherability.

As it is possible for water and brine to collect in the cavities, accelerated deterioration of the polyurethane in some environments may occur. To alleviate this problem drain holes are provided in the bottom of each cavity. Alternatively, cavities may be provided which are both inwardly open and outwardly open.

In a further form of this invention there is provided an apparatus for the production of a shock absorbing device of substantially polyurethane material: comprising a substantially hollow cylindrical drum part adapted to rotate about a cylindrical axis, said drum having a profiled inner surface comprising a plurality of inwardly projecting bosses adapted to produce cavities in a liquid material introduced to the cylinder; a support means adapted to support the cylindrical drum such that the cylindrical axis is substantially horizontal during rotation; means to produce rotation about the cylindrical axis; means to control the speed of rotation of the cylindrical drum; a means of introducing liquid material into the cylindrical drum; and means to maintain a temperature of said liquid.

In preference the means of introducing liquid material into the rotating cylinder comprises a channel containing a plurality of pouring spouts whose number and axial position corresponds to internal circumferential channels formed between the plurality of internal bosses located in the rotating mould, said plurality of internal bosses corresponding in radial and axial position to the plurality of outwardly opening cavities located on the surface of the shock absorbing device.

In preference said inwardly projecting bosses have a dimension and shape corresponding to the plurality of outwardly opened cavities contained within and extending radially inwards from the external cylindrical surface of the shock absorbing device such that their relationship is male to female within the terms of mold and pattern-making.

In preference the bosses are attached to essentially flat longitudinal bars which are movable either in a radial or axial direction with respect to the cylindrical drum to allow withdrawal of the completed shock absorbing device from the cylindrical drum.

In preference the cylindrical drum consists of a rigid hollow cylinder slightly larger in length and diameter than the dimensions of the marine fender to be produced to allow for the space taken up by said flat longitudinal bars.

Alternatively the bosses may be integrally formed with the longitudinal bars. The bars are longer than the fender to be cast but shorter that the rotating cylinder. A number of bars are distributed around the inner surface of the drum with a long axis of the bar being parallel to the rotating axis. The width and number of the bars is such that their longitudinal edges closely abut when affixed to the inner surface of the drum.

In preference the logitudinal bars are semi-rigid and capable of flexure, being preferably attached to the drum at each end.

The flexure of the bar aids in the stripping and removal from the drum of the shock absorbing device after moulding. There is also provided a slight arch in the bar which prevents vibrational damage at low rotational speeds when the drum is empty.

In preference there is provided a rigid removable plate or flange adapted to affix to the open ends of the hollow cylindrical drum to prevent liquid from leaking from the drum. These plates have a central circular open portion through which the means of introducing liquid to the drum enters.

There is also preferentially provided a means of circulating air internally through the cylindrical drum.

In a still further form of this invention there is provided a method of producing a polyurethane shock absorbing device having a plurality of cavities comprising the steps of mixing a polyurethane reaction mixture in predetermined proportions and introducing the mixture into a cylindrical drum rotating at a predetermined number of revolutions per minute; rotating the drum containing the mixture until such time as the polyurethane material reaches a tack phase; introducing a further mixture of the same or different composition and repeating the procedure a number of times, each time producing an additional layer, until a shock

absorbing device of the appropriate dimensions is produced.

A tack phase is a stage in the curing of the introduced liquid polyurethane material at which the surface is partly cured. Addition of additional material at this stage produces a bond between layers of substantial strength.

The elastomeric polyurethane is produced from a liquid polyurethane reaction mixture which is capable of solidifying by addition polymerization into an elastomeric material. This mixture may be prepared by the one shot, quasi-prepolymer or prepolymer methods using commercially available dispensing and mixing machines. The primary precursors are isocyanates, polyols and diols. Secondary precursors such as carbon pigments, anti-foaming agents or blowing agents can also be included to produce desired characteristics.

In particular the polyurethan reaction mixture is obtained from predominantly di-functional hydroxyl terminated compounds having average equivalent weights of 500 to 1500 and low average functionality polyisocyanates compounds. The isocyanite compounds preferably having a functionality less than 2.4.

The liquid polyurethan reaction mixture is capable of modification to produce specific variations in physical and chemical end properties of the solidified elastomeric material.

The modifications may include: varying the hydroxyl terminated compound as to its chemical composition; using two or more hydroxyl terminated compounds in various ratios; varying the processing conditions prior to or during final mixing; varying the order in which the various reactants are mixed; varying the functionality or equivalent weight of the hydroxyl terminated compounds; using two or more chemically different isocyanate compounds; varying the functionality of the isocyanate compounds; varying the stoichiometry of the reactants away from a theoretically balanced ratio.

The specific variations in properties of the reactant mixture and solidified elastomer may be further affected by the addition of difunctional chain extenders preferably having an equivalent weight of 150 or less. In addition, and always in combination with a chain extender, small quantities of trifunctional or

polyfunctional cross linkers may be added to the reactant mixture.

The cross linkers are preferably less than 10% by weight of the chain extender compounds.

The chain extender and cross linker compounds may be added to any of the previously mentioned reactant compounds either prior to or during the final reactant mixing operation.

Also certain compounds known in the field of polyurethane technology as additives may be blended with any of the previously mentioned reactant compounds, or any combination of these previously mentioned compounds either prior to or during final mixing of the polyurethan reaction mixture. The additive compounds may be reactive or non reactive towards any of the compounds previously mentioned as comprising the polyurethan reaction mixture.

A comprehensive list of additives and their uses is outlined in a publication entitled, "The Development and Use of Polyurethane Products" which has a Library of Congress catalogue card number 71-141918. This publication also contains a list of reactants which will combine with isocyanates.

To aid in the understanding of this invention preferred embodiments will be described with the aid of the following drawings, in which:

FIG. 1 is a perspective view of a first embodiment of a cylindrical shaped shock absorbing device of circular cross-section having a plurality of cavities;

FIG. 2 is a cross-sectional side view through the line AA of the shock absorbing device of FIG 1;

FIG. 3 is a cross-sectional end view through the line BB of the shock absorbing device of FIG. 1; showing the radial variation in hardness;

FIG. 4 is a cross-sectional end view as in FIG. 3 showing the radial

variation in hardness; and

FIG. 5 is a perspective view of a second embodiment of a cylindrical shaped shock absorbing device with a polygonal outer surface having a plurality of cavities.

Referring to the drawings, there is provided a shock absorbing device 1 of circular cross-section, having an outer surface 2, an inner surface 3 and two end surfaces 4. The inner surface 3 defines a hollow core 5 through which a support member may pass. Formed in the outer surface 2 are a number of outwardly open cavities 6 which are defined by an intervening wall system 7. For example this device may have an outer radius of 900 mm, an inner radius of 450 mm and a total length 2500 mm.

The cavities 6 are essentially square in this embodiment but may be of virtually any shape.

There may be provided drain holes in the cavities to allow water and brine to drain from the cavities which face upwards. In the absence of drain holes the shock absorbing device may experience accelerated deterioration. To further aid in the weather resisting properties of the device the outer layer may be formulated with fibrous reinforcement.

The device is produced by casting a first layer 8 with Shore A hardness of between 80 and 90. This layer is approximately 25 mm thick. A second layer 9 of 50 mm thickness is cast with a hardness of 75-80A. This is followed by a third layer 10 which is also approximately 50 mm thick and has a hardness of 55-75A. Finally an innermost layer 11 is cast of 80-90 Shore A hardness and approximately 25 mm thickness.

A preferred formulation consists of: mixed glycol polyols based on combinations of ethylene and/or diethylene and/or butylene-adipate of equivalent weight of 1000; 1,4 Butane diol and for harder formulations some trimethyl propane; and 4,4 Diphenylmethane di-isocyanate. The hardness may be varied by altering the ratio of polyol to diol. For a soft formulation with approximately Shore A hardness of 45 no diol is used and the reactants are mixed in the proportion:

1 equivalent weight of Polyol : 1 equivalent weight of Isocyanate.

For a hard formulation with approximate shore D hardness of 50 the reactants are mixed in the proportion:

1 equivalent weight of Polyol: 5 equivalent weight of 1,4 Butane Diol : 6 equivalent weight of Isocyanate

the exact hardness and properties depends on the variations in processing and amount of the trimethyl propane used to replace some 1,4 Butane Diol, and any slight variation on the NCO percentage. Obviously other hardnesses may be obtained by using other ratios of polyol to diol.

A second embodiment 12 varies from the first in that the outer surface 13 is of a polygonal shape. The cavities 14 are similar to those of the first embodiment.

THE CLAIMS DEFINING THE INVENTION ARE AS FOLLOWS:

1. A shock absorbing device comprising polyurethane material of a substantially cylindrical construction having an outer surface an inner surface and two end surfaces said inner surface defining a void through which a supporting member may pass.

2. The shock absorbing device of claim 1 having a circular, polygonal or D cross-section.

3. The shock absorbing device of claim 1 in which there are provided a plurality of cavities formed in the outer surface and extending towards the inner surface.

4. The shock absorbing device of claim 3 in which the cavities are defined by an intervening wall system.

5. The shock absorbing device of claim 4 in which said walls are of substantially constant cross-sectional width.

6. The shock absorbing device of any of claims 3 to 5 in which the cavities extend substantially from the outer surface to the inner surface.

7. The shock absorbing device of claim 5 in which the cavities extend two-thirds of the way from the outer surface to the inner surface.

8. The shock absorbing device of any of the preceding claims in which the polyurethane material is of a different characteristic at a first radial distance from the inner surface as compared to another radial distance from the inner surface.

9. The shock absorbing device of claim 8 in which the hardness of the polyurethane material varies from the outer surface to the inner surface.

10. The shock absorbing device of claim 7 in which the hardness is greatest at the surfaces and least between the surfaces and varies in layers between the surfaces.

11. An apparatus for the production of a shock absorbing device of substantially polyurethane material: comprising a substantially hollow cylindrical drum part adapted to rotate about a cylindrical axis, said drum having a profiled inner surface comprising a plurality of inwardly projecting bosses adapted to produce cavities in a liquid material introduced to the cylinder; a support means adapted to support the cylindrical drum such that the cylindrical axis is substantially horizontal during rotation; means to produce rotation about the cylindrical axis; means to control the speed of rotation of the cylindrical drum; a means of introducing liquid material into the cylindrical drum; and means to maintain a temperature of said liquid.

12. The apparatus of claim 11 in which the means of introducing liquid material into the rotating cylinder comprises a channel containing a plurality of pouring spouts whose number and axial position corresponds to internal circumferential channels formed between the plurality of internal bosses located in the rotating mould, said plurality of internal bosses corresponding in radial and axial position to the plurality of outwardly opening cavities located on the surface of the shock absorbing device.

13. The apparatus of claim 11 in which the cylindrical drum consists of a rigid hollow cylinder slightly larger in length and diameter than the dimensions of the marine fender to be produced.

14. The apparatus of claim 11 in which the inwardly projecting bosses have a dimension and shape corresponding to the plurality of outwardly opened cavities to be contained within and extending radially inwards from the external cylindrical surface of the shock absorbing device such that their relationship is male to female within the terms of mold and pattern-making.

15. The apparatus of claim 14 in which said bosses are attached to essentially flat longitudinal bars which are movable either in a radial or axial direction with respect to the cylindrical drum to allow withdrawal of the completed shock absorbing device from the cylindrical drum.

16. The apparatus of claim 11 in which there is provided rigid removable plates

or flanges adapted to affix to the open ends of the hollow cylindrical drum to prevent liquid from leaking from the drum, said plates having a central circular open portion through which the means of introducing liquid to the drum is positioned.

17. A method of producing a polyurethane shock absorbing device having a plurality of cavities comprising the steps of mixing a polyurethane reaction mixture in predetermined proportions and introducing the mixture into a cylindrical drum rotating at a predetermined number of revolutions per minute; rotating the drum containing the mixture until such time as the polyurethane material reaches a tack phase; introducing a further mixture of the same or different composition and repeating the procedure a number of times, each time producing an additional layer, until a shock absorbing device of the appropriate dimensions is produced.

18. A shock absorbing device as herein described with reference to the attached drawings.

AMENDED CLAIMS
[received by the International Bureau on 15 October 1991 (15.10.91);
original claims 1-32 replaced by amended claims 1-18 (5 pages)]

1. A shock absorbing device of substantially tubular shape, constituted by being manufactured from predominantly elastomeric material; having an inner surface defining a hollow core, two end surfaces, and a characterising webbed outer surface formed from a plurality of integrally connected members whose sides enclose a plurality of outwardly opened cavities extending from the outer surface towards the inner surface.

2. The shock absorbing device of claim 1, in which co-aligned interconnecting members have similar cross-sections and dimensions.

3. The shock absorbing device of claim 1, in which the outwardly opened cavities have a radial depth which is a substantial proportion of the total thickness of the tubular wall, the depth being within the range of 1/4 to 2/3 of the tubular wall thickness.

4. The shock absorbing device of claim 1, in which at least part of the outwardly opened cavities extend all the way from the outer surface to the inner surface.

5. The shock absorbing device of claim 1, in which the outwardly opened cavities extend over a substantial portion of the outer surface.

6. The shock absorbing device of claim 1, in which the extended axis of the outwardly opened cavities intersect the central axis of the tubular shock absorbing device.

7. The shock absorbing device of claim 1, in which the elastomeric material is of a different characteristic at a first radial distance from the centre axis of the inner surface as compared to another radial distance from that axis; thus providing a layered circumferential skin effect in which the hardness or shear modulus G varies between the inner and outer surfaces, such that the hardness or shear modulus G is greatest within the layers at these surfaces and less within the layers between these inner and outer layers.

8. The shock absorbing device of claim 7, in which the layer with the lowest hardness or shear modulus G is located at that operative neutral fibre-

stress axis which meets the desired specification, during that regime when the shock absorber device is radially loaded up to the point at which the hollow core has closed.

9. The shock absorbing device of claim 1, in which the predominantly elastomeric material is a polyurethane.

10. The shock absorbing device of claim 1, in which the elastomeric material is comprised partly or wholly of a microcellular foam.

11. The shock absorbing device of claim 1, in which the elastomeric material is reinforced with fibres.

12. A shock absorbing device of substantially tubular shape, constituted by: being manufactured from predominantly elastomeric material; having an inner surface defining a hollow core, an outer surface and two end surfaces; having elastomeric material of a different characteristic at a first radial distance from the centre axis of the inner surface, as compared to another radial distance from that axis, thus providing a layered circumferential skin effect; being characterised in that at least three layers of variable hardness or shear modulus G, exist between the inner and outer surfaces, that the hardness or shear modulus G is greatest within the layers at these surfaces and less within the layers between these inner and outer layers, and that the layer with the lowest hardness or shear modulus G is located at that operative neutral fibre-stress axis which meets the desired specification, during that regime when the shock absorber device is radially loaded, up to the point at which the hollow core has closed.

13. An apparatus for the production of substantially tubular shaped devices moulded from settable fluid materials; the apparatus, which consists of a mould adapted to rotate about it's axes, comprises: a hollow tubular container part having an inner surface, an outer surface and two open ends, said tubular container being free to rotate about a first longitudinal axis which passes through the open ends of the tubular container; support means adapted to support the tubular container so that its longitudinal axis is preferably horizontal during rotation; means to produce rotation about a longitudinal axis; means to control the speed of rotation of the tubular container; means of introducing a settable fluid material into the tubular container; means of

preventing the introduced fluid material from spilling or leaking out of the ends of the tubular container; means to control the temperature of the tubular container and its contents; means of circulating air internally through the tubular container; means to produce a plurality of cavities in a settable fluid material introduced into the tubular container, said means consisting of the plurality of cavities being formed by having a profiled inner surface within the tubular container, said profiled inner surface being characterised by having a plurality of inwardly projecting bosses attached to or integral with a plurality of longitudinal members which are distributed around the inner surface of the tubular container.

14. The apparatus of claim 13 in which the plurality of inwardly projecting bosses have a dimension and shape corresponding to the plurality of outwardly opened cavities to be contained within and extending radially inwards from the external surface of the substantially tubular shaped device, such that their relationship is male to female within the terms of mould and pattern making.

15. The apparatus of claim 13 in which the longitudinal members extend between the open ends of the tubular container and are affixed there by their extremities.

16. The apparatus of claim 13 in which the longitudinal members are affixed to each other and the inner surface of the tubular container by releasable mechanical means.

17. The apparatus of claim 13 in which the longitudinal members are integral with, and form part of the walls of the tubular container.

18. The apparatus of claim 13 in which the longitudinal members have a longitudinal axis which is parallel to the rotating axis of the tubular container.

19. The apparatus of claim 13 in which the longitudinal members have a longitudinal axis which is biased to the rotating axis of the tubular container.

20. The apparatus of claim 13 in which the longitudinal members are of a shape, width and number such that their longitudinal edges closely abut,

when affixed to each other and to the inner surface of the tubular container in a releasable manner.

21. The apparatus of claim 13 in which the longitudinal members are adapted to be moved, either in a radial and an axial direction with respect to the tubular container, thereby allowing de-moulding of the completed tubular shaped device.

22. The apparatus of claim 13 in which the longitudinal members are semi-rigid and capable of flexure thereby allowing for a gradual de-moulding procedure requiring less stripping force.

23. The apparatus of claim 13 in which the longitudinal members are provided with a slight arch, so that when they are affixed to the inner surface of the tubular container at their extremities, the centres of the longitudinal members are strongly biased towards the adjacent surface of the tubular container, thereby forcing the longitudinal members to lie against this adjacent surface with sufficient force to prevent vibrational damage at low rotational speeds when the tubular container is empty.

24. The apparatus of claim 13 in which the tubular container is slightly larger in length and diameter than the substantially tubular shaped device moulded therein from settable fluid materials.

25. The apparatus of claim 13 in which the longitudinal members are shorter than the tubular container, but longer than the substantially tubular shaped device moulded therein from settable fluid materials.

26. The apparatus of claim 13 in which the means of preventing the introduced fluid material from spilling or leaking out of the ends of the tubular container consists of rigid removable plates or flanges adapted to be affixed to the open ends of the tubular container, said plates having a central aperture through which the means of introducing a settable fluid material into the tubular container is positioned.

27. The apparatus of claim 13 in which the means of introducing settable fluid material into the rotating tubular container comprises a channel containing a plurality of pouring spouts whose number and axial position

corresponds to the internal circumferential channels formed between the plurality of internal bosses located in the rotating mould, said plurality of internal bosses corresponding in radial and axial position to the radial and axial position of the plurality of outwardly opened cavities located within the outer surface of the substantially tubular shaped device.

28. The apparatus of claim 13 in which the settable fluid material used is capable of setting into an elastomer.

29. The apparatus of claim 13 in which the settable fluid material used is capable of setting into a polyurethane elastomer.

30. The apparatus of claim 13 in which the method used for the production of substantially tubular shaped devices moulded from settable fluid materials comprises the steps of mixing a polyurethane reaction mixture in predetermined proportions and introducing the mixture into the tubular container rotating at a predetermined number of revolutions per minute; maintaining that rotation until such time as the polyurethane material reaches a tack phase; introducing a further mixture of the same or different composition and repeating the procedure a number of times, each time producing an additional layer, until a substantially tubular shaped device of the appropriate dimensions is produced.

31. The apparatus of claim 13 in which the substantially tubular shaped device moulded from settable fluid materials is a shock absorber.

32. A shock absorbing device substantially as herein described in the specification with reference to and as illustrated by the accompanying drawings.

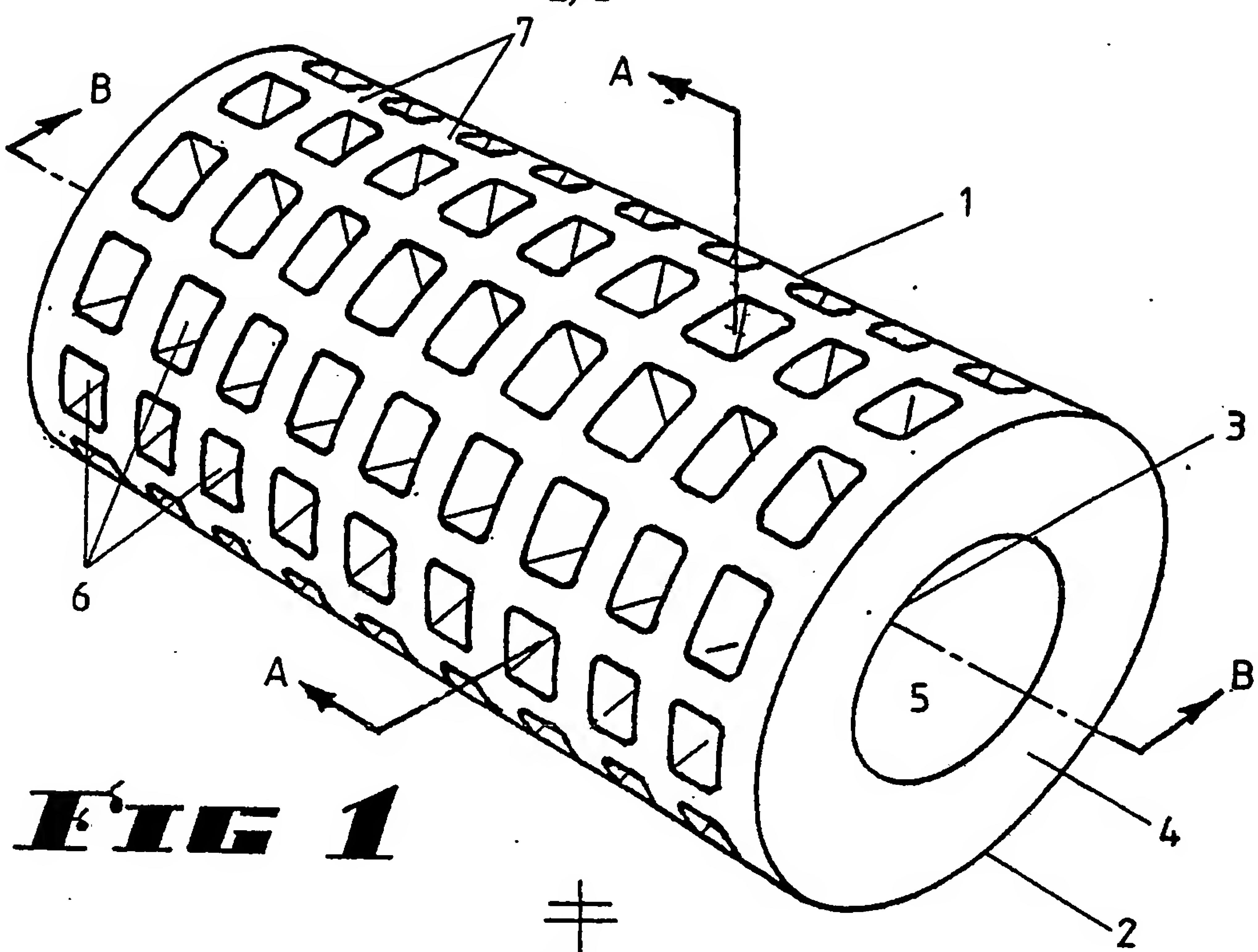

FIG 1

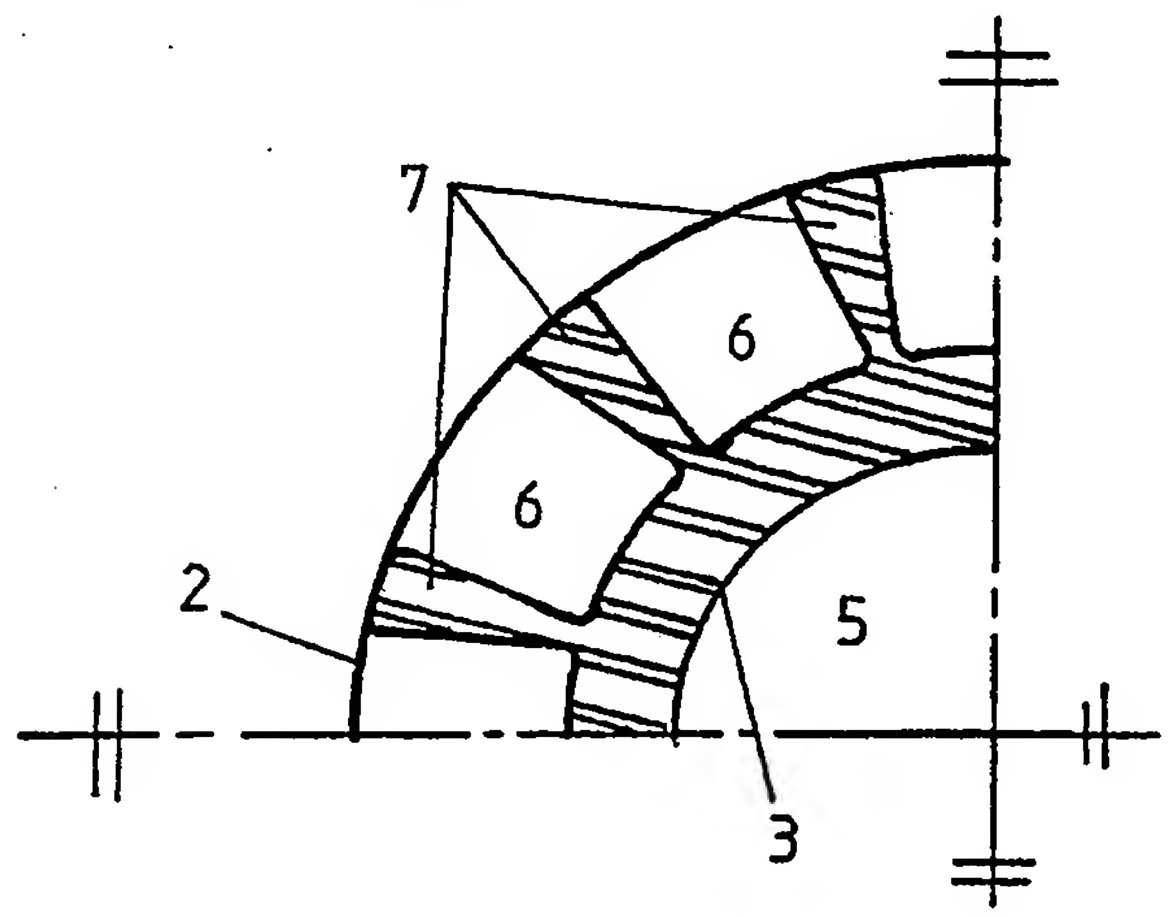

FIG 2

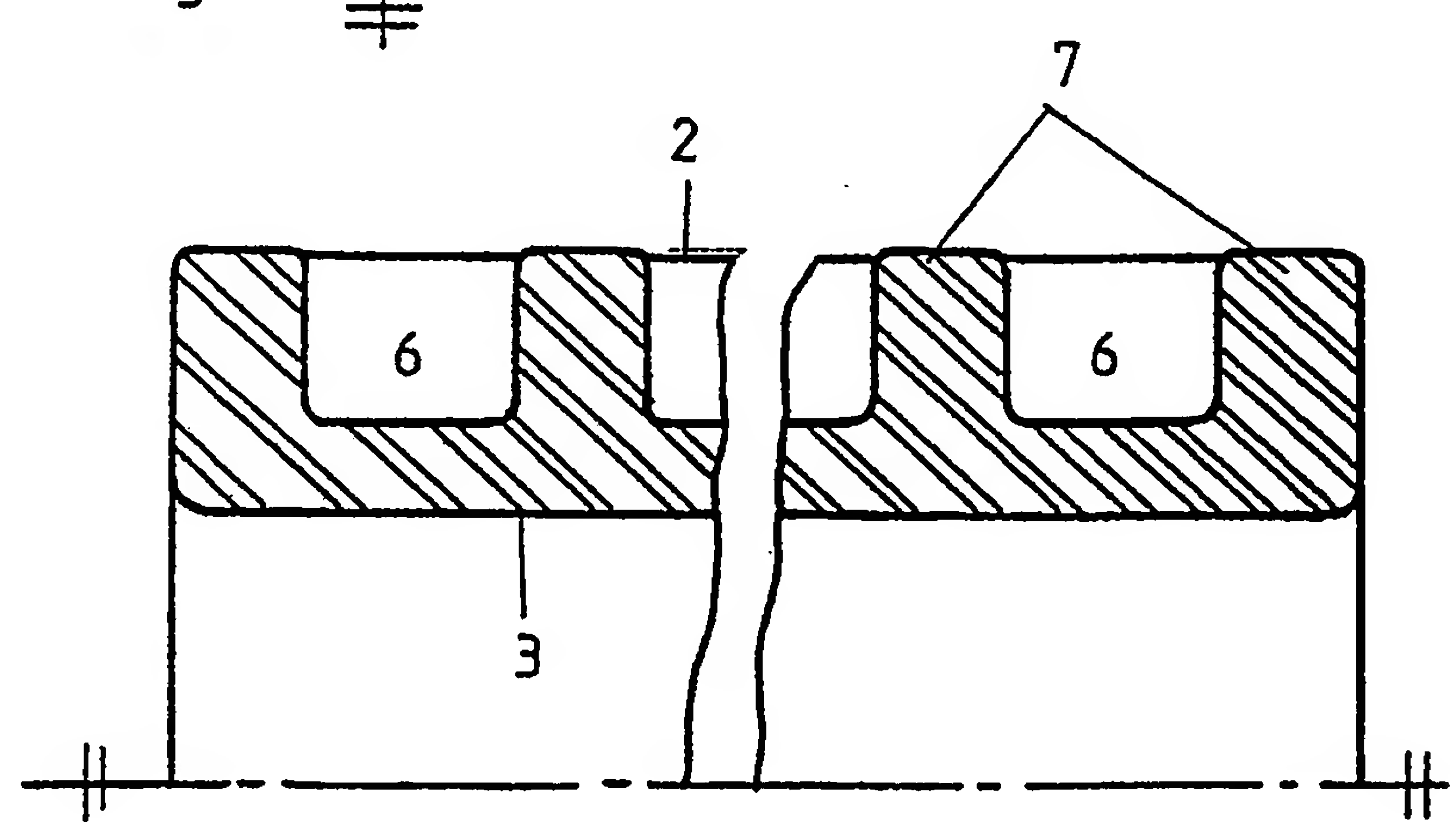

FIG 3

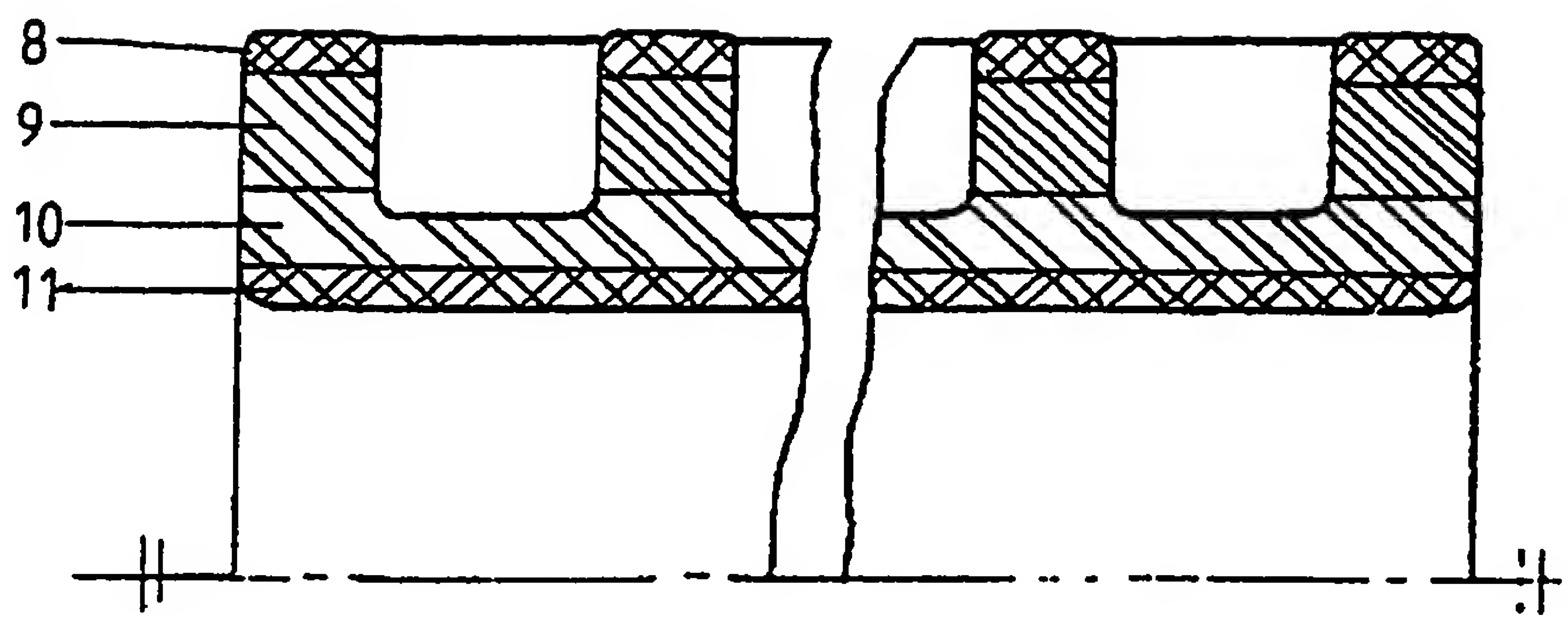

FIG 4

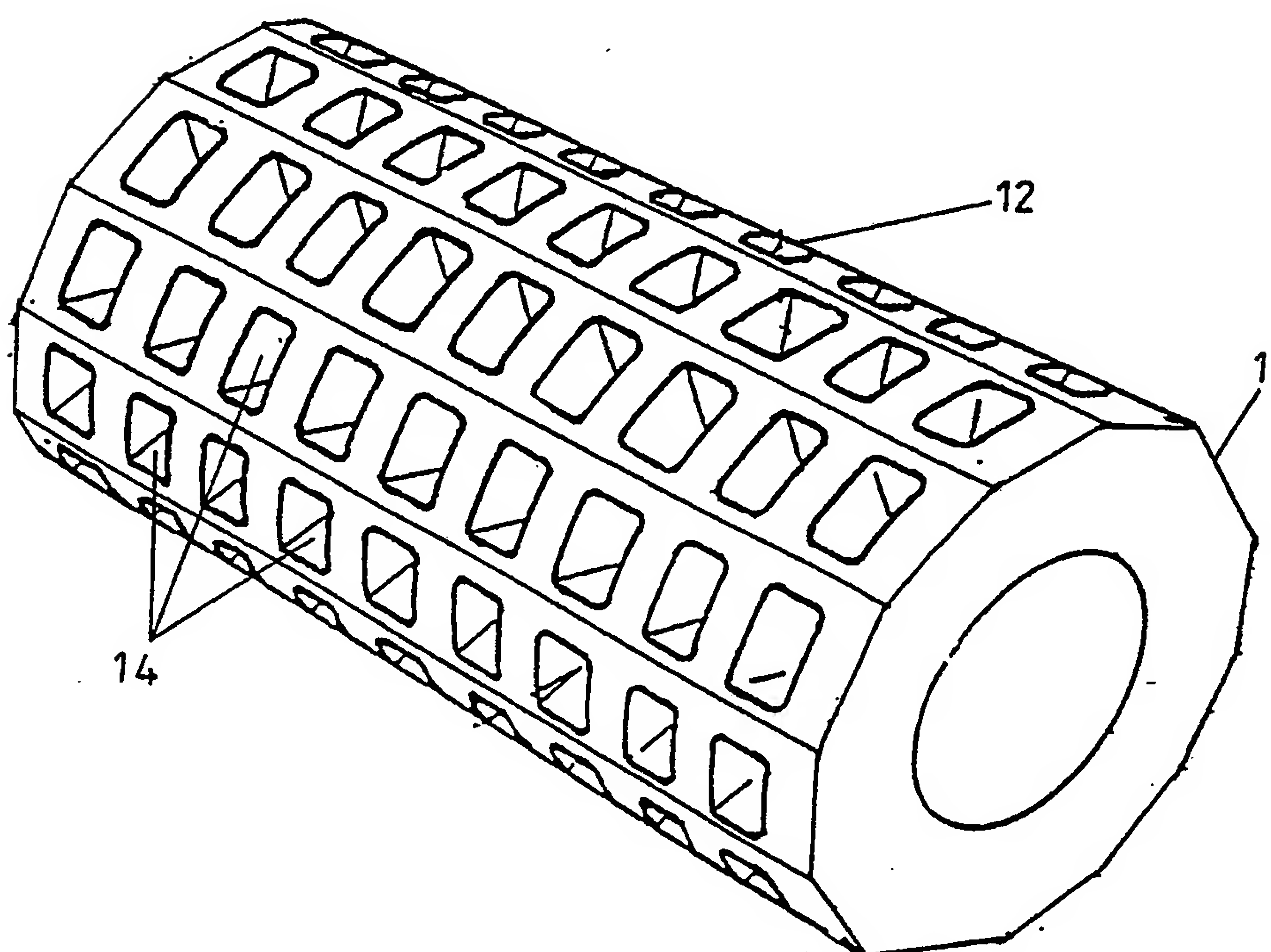

FIG 5